STATUS OF RAINBOW TROUT IN THE GOODNEWS RIVER, TOGIAK NATIONAL WILDLIFE REFUGE, ALASKA 1988-1989

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ABSTRACT

The population characteristics of rainbow trout (*Oncorhynchus mykiss*) in the Goodnews River on the Togiak National Wildlife Refuge (Refuge) were studied from June through September, 1988 and 1989. The study objectives were to: (1) describe length, weight, age, and sex composition of rainbow trout; (2) estimate the annual survival rate of each year class of rainbow trout vulnerable to the sport fishery; (3) estimate seasonal sport fishing catch rates of rainbow trout; (4) evaluate scale versus otolith ageing methods; (5) compare rainbow trout population characteristics with other southwest Alaska stocks; and (6) describe length and weight data of Dolly Varden and Arctic Char (*Salvelinus* sp.) and Arctic grayling (*Thymallus arcticus*).

Three hundred and eighty-seven rainbow trout were captured using hook and line, minnow traps, and electrofishing. Lengths ranged from 27-686 mm and weights from 1-2,550 g. Otolith ages ranged from 0-11 years and scale ages ranged from 0-8 years. The female to male sex ratio was 1:2.04. Comparisons between scale and otolith aged rainbow trout revealed that scale ages underestimated the otolith age by 1-3 years for fish 3 years and older.

The Goodnews fish populations were compared to those of the Kanektok River. More large rainbow trout were caught in the Goodnews River than in the Kanektok River. Goodnews River rainbow trout also exhibited larger length at age than fish from the Kanektok River. However, creel survey data revealed that catch rates of rainbow trout from the Goodnews River were one-third that of the Kanektok River. Based on catch data, the population probably does not have the capacity to support large increases in fishing pressure without suffering a decrease in the size composition.

One hundred and seventy-five *Salvelinus sp.* and 130 Arctic grayling were also sampled. *Salvelinus sp.* lengths and weights ranged from 278-629 mm and 225-2,825 g, and Arctic grayling ranged from 275-510 mm and 250-1,550 g, respectively. These species were found to be slightly larger than other Arctic grayling and *Salvelinus sp.* populations in southwestern Alaska.

We recommend continued monitoring of the sport fishery through the Refuge's Special Use Permits and public use surveys; that the resident fish populations be sampled again in five years to note any changes in size composition; and that a conservative approach be practiced in management of the Goodnews River rainbow trout population.

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INTRODUCTION

The angling opportunities for rainbow trout (*Oncorhynchus mykiss*) on the Togiak National Wildlife Refuge (Refuge) are one of the primary attractions for visitors. The estimated number of angler use days per year increased approximately eleven-fold on the Kanektok River, fifteen-fold on the Togiak River, and two-fold on the Goodnews River from 1981 to 1986 (U.S. Fish and Wildlife Service 1986). From 1984 to 1992, the Goodnews River has averaged 2400 angler days per year (Lisac 1989, MacDonald 1993). As high levels of use continue, both the number and size of fish could decrease. In particular, the potential for overfishing of rainbow trout is a concern to the public, State of Alaska, and the U.S. Fish and Wildlife Service (Service). However, knowledge of the resident fishery resource in the Goodnews River, the uses people make of this resource, and the effects of uses upon the resource are inadequate for their sound scientific management (U.S. Fish and Wildlife Service 1986). Additional information is needed to refine management objectives, develop detailed management plans, determine trends, evaluate management effectiveness, identify existing and potential problems, and generally meet the needs of Refuge management.

Little biological information had been gathered on Goodnews River rainbow trout prior to this study. A total of 74 rainbow trout were collected on the North Fork of the Goodnews River in 1975 (Alt 1977) and 84 on the Middle Fork of the Goodnews River in 1985 (Alt 1986). They ranged in length from 124-630 mm (scale ages 1-11) in 1975 and 322-602 mm and 400-2,650 g (scale ages 3-10) in 1985.

Data on subsistence harvest of resident fish from the Goodnews River are limited. Rainbow trout are harvested by subsistence fishers primarily from the village of Goodnews (Wolfe et al. 1984), though the magnitude of this harvest is unknown. Gill nets are the principal gear employed, although hook and line, jigging, and seines are also used.

Sampling on the Kanektok River from 1985 to 1987 identified a discrepancy between ageing rainbow trout using scales and otoliths (Wagner 1991). Scales under aged catchable rainbow trout (>250 mm) by 1 - 3 years. Scales are a questionable tool to obtain the best age composition of a population. As the Refuge fishery resources are managed to conserve fish populations and habitats in their natural diversity and preserve their historical length and age composition (U.S. Fish and Wildlife Service 1986), accurate age data are needed.

To meet these information needs, the King Salmon Fishery Resource Office sampled the rainbow trout population on the Goodnews River in 1988 and 1989. When this study was proposed in 1987, there was relatively little public use on the Goodnews River. The majority of the increased effort was focused toward the Kanektok River. It was thought that the Goodnews River rainbow trout population could be compared with more heavily exploited populations on the Refuge to determine the effects of sport fishing. The goals of the study were to primarily provide population information on rainbow trout with a limited assessment of Arctic grayling (*Thymallus arcticus*) and char (*Salvelinus* sp.), determine the effects of different aging techniques on estimating population

parameters of rainbow trout, and determine if the Goodnews River rainbow trout population could be used as a benchmark of an unexploited rainbow trout population. The specific objectives were to:

1. Describe length, weight, age and sex data of rainbow trout.

2. Estimate the annual survival rate of each year class of rainbow trout vulnerable to the sport fishery.

3. Estimate seasonal sport fishing catch rates of rainbow trout.

4. Evaluate scale versus otolith ageing methods.

5. Compare rainbow trout population characteristics of the Goodnews River with other stocks in southwestern Alaska.

6. Describe length and weight data of resident char and Arctic grayling.

STUDY AREA

The Goodnews River originates in the Togiak National Wildlife Refuge and flows southwest into Goodnews Bay. The total drainage is approximately 2,600 km^2 and consists of three major branches (Figure 1). The North Fork flows from Goodnews Lake about 76 river kilometers (Rkm) to Goodnews Bay. The two other branches, the Middle and South Forks, enter the North Fork about 5 Rkm from Goodnews Bay (Alt 1977). Only the upper portion of each branch is within the Togiak National Wildlife Refuge.

The three branches of the Goodnews River are generally braided. The riparian habitat consists of willow (*Salix* sp.), alder (*Alnus* sp.), cottonwood (*Populus* sp.), and tundra vegetation. The majority of the river has fine to medium gravel and cobble present, but ranges from areas of bedrock and boulder rapids in the upper reaches to silt and sand in the lower reaches.

The Goodnews Bay coastal region is primarily moderate polar maritime, but can be affected by the weather of interior Alaska. The average summer air temperatures range from 3 to 19 °C and winter air temperatures range from -16 to -1 °C. Annual precipitation ranges from 51-66 cm. Annual snowfall averages 152-178 cm along the coast, but may exceed 381 cm in the mountains (U.S. Fish and Wildlife Service 1990).

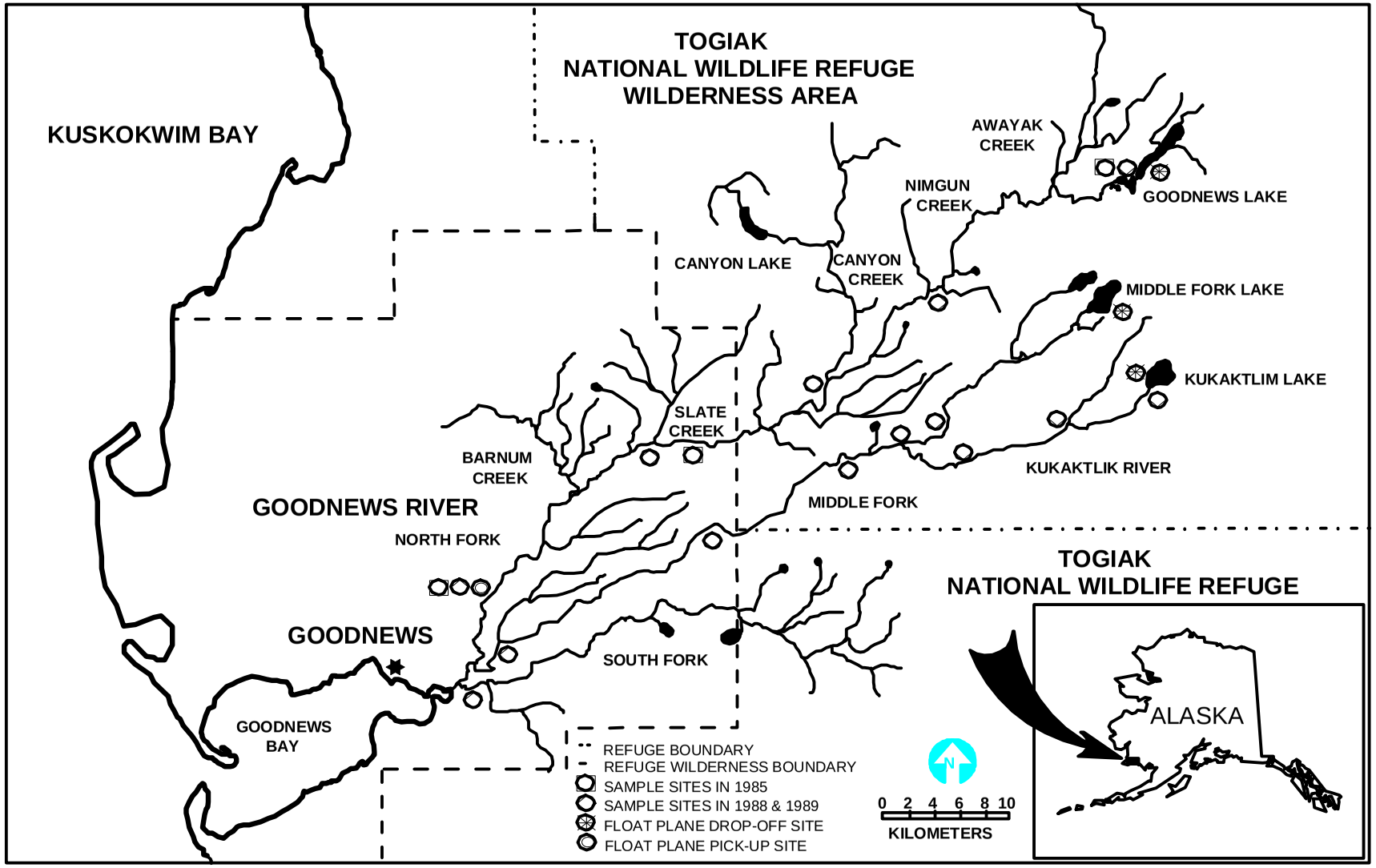

Figure 1.-Goodnews River drainage and study area, Togiak National Wildlife Refuge, Alaska, 1988 and 1989.

METHODS

Length and Weight Composition

The rainbow trout population of the Goodnews River was sampled from June through September 1988-89. Float planes transported crews and gear to sampling locations where outboard jet boats, rubber rafts, and hiking were used to access sampling areas. Sampling on the North and Middle Forks of the Goodnews River and the Kukaktlik River was conducted from their headwater lakes to their mouths. Sampling on the South Fork was conducted only on the lower end. Temporary camps were set up for 1-3 days on gravel bars to sample the river and smaller tributaries.

Hook and line was the primary method used to sample fish. Baited minnow traps and a Smith-Root Model 15-A backpack electrofisher were used to sample juvenile fish. Sampling was conducted along undercut banks, root wads, and log jams of the river and tributaries. Six to twenty minnow traps were set in the evening and left overnight. Traps were checked each day at midmorning. The backpack electrofisher was used to sample areas for 10-20 minutes 2-4 times each day.

Fork length (FL) to the nearest mm, and weight to the nearest gram (g) were measured. Functional regression analysis (Sokal and Rohlf 1981, Draper and Smith 1981) was used to estimate the length-weight relationship for rainbow trout. An analysis of covariance compared the differences between slopes (Sokal and Rohlf 1981). An analysis of variance (Sokal and Rohlf 1981) tested the differences in lengths and weights of rainbow trout between subdrainages. All statistical comparisons were made at the P=0.05 level.

Relative stock density categories based on fork length (Wege and Anderson 1978) was estimated for rainbow trout. Length categories were adapted from Gabelhouse (1984) and adjusted for resident stream dwelling Alaska rainbow trout from Wagner (1991). The relative stock density categories were Stock <299 mm; Quality 300-399 mm; Preferred 400-499 mm; Memorable 500-599 mm; and Trophy $\geq$ 600 mm. A G-test (P=0.05) (Sokal and Rohlf 1981) tested the differences in relative stock density distributions between rainbow trout populations within the Goodnews River subdrainages.

Age Composition

Scales were collected from the preferred scale area (Jearld 1983) from all rainbow trout. Ages of scales were estimated using techniques reported by Koo (1962). Ages were interpreted by two to three readers. An additional reader resolved disagreements. Regenerated scales were discarded.

A sub-sample of 2-10 rainbow trout per 25 mm length class were sacrificed for extraction of sagittal otoliths. During collection and transport, otoliths were stored dry in plastic sample tubes. In preparation for reading otoliths were either: (1) stored in a 2:3 glycerine:alcohol solution (Jearld 1983), cleared with clove oil, and ground with a whetstone; or (2) cleared with xylene and read whole.

Otoliths were viewed with a microscope (Brothers 1987). Otolith annuli were interpreted according to Barber and McFarlane (1987). Two to three readers estimated ages of otoliths. An additional reader resolved disagreements. Unreadable otoliths were discarded.

Ages of scales and otoliths from the same fish were compared to assess the validity of scale versus otolith ageing techniques of rainbow trout.

The scale age frequency distribution was modified from the otolith age frequency distribution using the following equation from Wagner (1991):

$$E_j = \sum_{i,j=1}^{N} [(S_i * A_{ij}) \div T_i] \quad \textbf{(1)}$$

where:

E_j = the estimated number of corrected scale aged j fish
S_i = the total number of scale aged i fish in the scale aged sample
A_{ij} = the number of otolith age j fish in the scale age i category of the otolith and scale aged sample
T_i = the total number of scale age i fish in the otolith and scale aged sample

Scale and adjusted scale age frequency distributions were compared with a *G*-test (P=0.05).

Because the otolith samples were not randomly selected, otolith age composition was estimated based on otolith ages and length frequency distributions. An equal number of samples were selected from each 25 mm FL interval and the proportion of each otolith age in each length interval was calculated. The otolith age composition was adjusted based on the length frequency distribution. The equation is:

$$E_j = \sum_i (P_{ij} * L_i) \quad \textbf{(2)}$$

where:

E_j = the estimated number of otolith aged j fish
P_{ij} = the proportion of otolith age j fish in the i 25 mm length interval
L_i = the number of measured fish (FL) in the i 25 mm length frequency category

Mean length and weight at age was based on scale ages to enable comparison of data between rivers. Mean lengths at age were compared using *t*-tests (P=0.05) (Sokal and Rohlf 1981).

Sex Composition

Rainbow trout that were sacrificed for otolith collection were dissected to determine sex.

Survival Estimates

Annual survival rate was estimated from catch curve analysis (Chapman and Robson 1961) for scale and adjusted scale ages of rainbow trout caught by hook and line. The first year beyond the modal age of the catch curve was considered the youngest fully recruited age (Ricker 1975). Annual mortality rates (Ricker 1975) based on scale and adjusted scale ages were compared.

Effort and Catch Estimates

Information for catch and fishing effort from guided anglers was taken from Special Use Permit data (U.S. Fish and Wildlife Service 1990). Use information for one guide operation was not supplied and was estimated from 1987 guide records.

Southwest Alaska Rainbow Trout Stock Comparisons

Length, weight, age, sex composition, and survival estimates of rainbow trout from the Goodnews River were compared with similar estimates for rainbow trout from the Kanektok River (Wagner 1991). A G-test (Sokal and Rohlf 1981) was used to test for differences in length frequency distributions. Regression analysis (Sokal and Rohlf 1981, Draper and Smith 1981) was used to estimate the length-weight relationships. An analysis of covariance compared the differences between slopes (Sokal and Rohlf 1981). A G-test was used to test the differences in relative stock density category values. A t-test was used to test for differences between mean lengths of otolith aged rainbow trout from the Goodnews and Kanektok Rivers (Sokal and Rohlf 1981). All statistical comparisons were made at the P=0.05 level.

Other Species

All fish were identified to species except Dolly Varden and Arctic char. Because gill rakers and pyloric caeca counts are needed to distinguish between Dolly Varden (*Salvelinus malma*) and Arctic char (*S. alpinus*), they were not identified to species to reduce handling stress. They are referred to as *Salvelinus* sp. in this report. Fork length (mm) and weight (g) were measured from a subsample of all captured *Salvelinus* sp. and Arctic grayling.

RESULTS

Length and Weight Composition

A total of 387 rainbow trout were captured in 1988 and 1989 (Table 1). Fork length ranged from 27-686 mm (Figure 2). The North Fork had significantly smaller (P<0.005) mean lengths of rainbow trout than the Middle Fork, Kukaktlik River, and the South Fork. Mean lengths of rainbow trout of the Middle Fork were significantly smaller (P<0.005) than the Kukaktlik River. The length weight regression for all subdrainages combined (Figure 3) were calculated.

The relative stock density category values of rainbow trout in the Goodnews River drainage were 12% Stock, 24% Quality, 38% Preferred, 24% Memorable, and 2% Trophy. The majority of rainbow trout in the North Fork (53%), Middle Fork (71%), Kukaktlik River (87%), and South Fork (63%) were in the Preferred and Memorable relative stock density categories (Figure 4). Relative stock density category values differed significantly (P<0.005) among all subdrainages except between the Kukaktlik River and South Fork. Relative stock density category values differed significantly (P<0.005) between 1985 and 1988 (Figure 5).

For ages over 2, mean lengths at age were greater for scale aged fish than otolith aged fish (Tables 2 and 3).

Age Composition

Two hundred and ninety six rainbow trout had readable scales, and 91 (24%) were regenerated. The percentage of regenerated and unreadable scales increased as the size and age of the rainbow trout increased (Figures 6 and 7).

Otoliths were taken from 149 rainbow trout of which 21 (14%) were unreadable. A sample of 122 rainbow trout had both readable scales and otoliths that could be used to compare otolith and scale ages. Scale ages ranged from 0-8 years and otolith ages from 0-11 years. Comparisons between scale and otolith aged rainbow trout reveal that scale ages underestimated the otolith ages by 1-3 years for those fish 3 years of age and older (Figure 8). Eighty rainbow trout (66%) were assigned the same scale and otolith age. Scale, adjusted scale age, and otolith distributions (Figure 9) were significantly different (P<0.005).

Age classes that corresponded to the relative stock density categories for otolith aged rainbow trout were examined. Ages of rainbow trout in the preferred category (400-499 mm) ranged from 4-9 years with a modal age of 6 years (Figure 10).

Sex Composition

Of the 387 rainbow trout sampled, sex data was collected from 152 fish. The female (N=50) to male (N=102) ratio was 1:2.04. More females were caught in June (85%), whereas more males were caught in July (69%) and August (72%). Most rainbow trout were sampled in August. The length weight regression for each sex and combined sexes were calculated

Table 1.-Length and weight data of rainbow trout captured with hook and line, electrofishing, and minnow traps, Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

			Length (mm)			Weight (g)		
Year	Drainage	N	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
1988	North Fork	171	411.0	87.2	134-601	959.7	504.0	29-2,550
	Middle Fork	37	436.4	85.3	197-604	1,007.6	533.3	100-2,220
	Kukaktlik R.	-	-	-	-	-	-	-
	South Fork	30	462.6	85.7	313-615	1,266.7	598.4	330-2,350
	Total	238	421.5	88.2	134-615	1,005.9	528.5	29-2,550
1989	North Fork	31	339.8	169.9	83-686	743.4	677.5	5-2,500
	Middle Fork	95	424.2	133.0	27-610	1,120.0	598.6	1-2,200
	Kukaktlik R.	23	480.7	68.8	305-575	1,452.2	523.7	350-2,250
	South Fork	-	-	-	-	-	-	-
	Total	149	415.4	140.4	27-686	1,092.9	638.3	1-2,500
Both	North Fork	202	400.1	106.8	83-686	926.5	538.0	5-2,550
	Middle Fork	132	427.6	121.3	27-610	1,088.5	581.2	1-2,200
	Kukaktlik R.	23	480.7	68.8	305-575	1,452.2	523.7	350-2,250
	South Fork	30	462.6	85.7	313-615	1,266.7	598.4	350-2,350
	Total	387	419.1	111.1	27-686	1,039.4	574.1	1-2,550

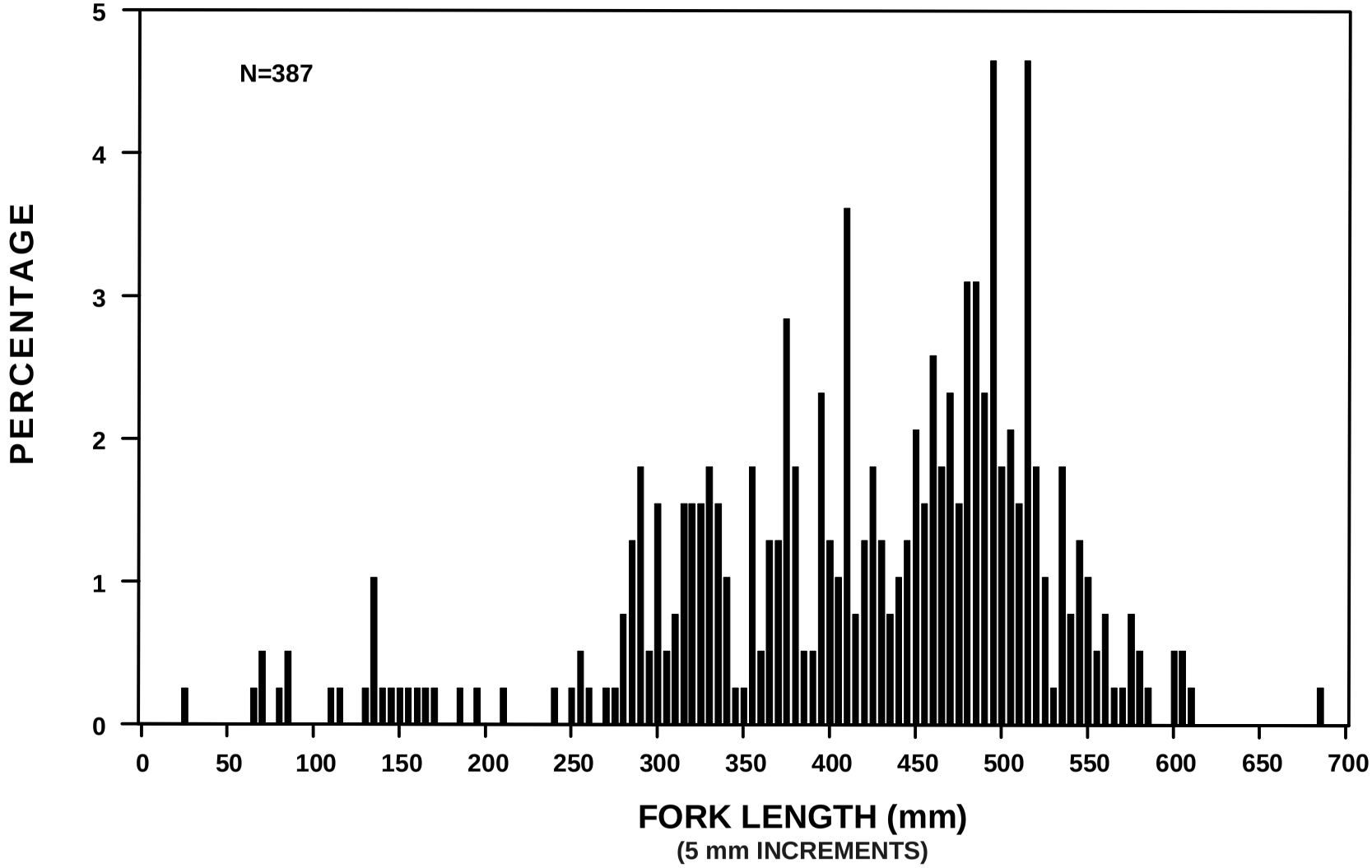

Figure 2.-Length frequency distribution of rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

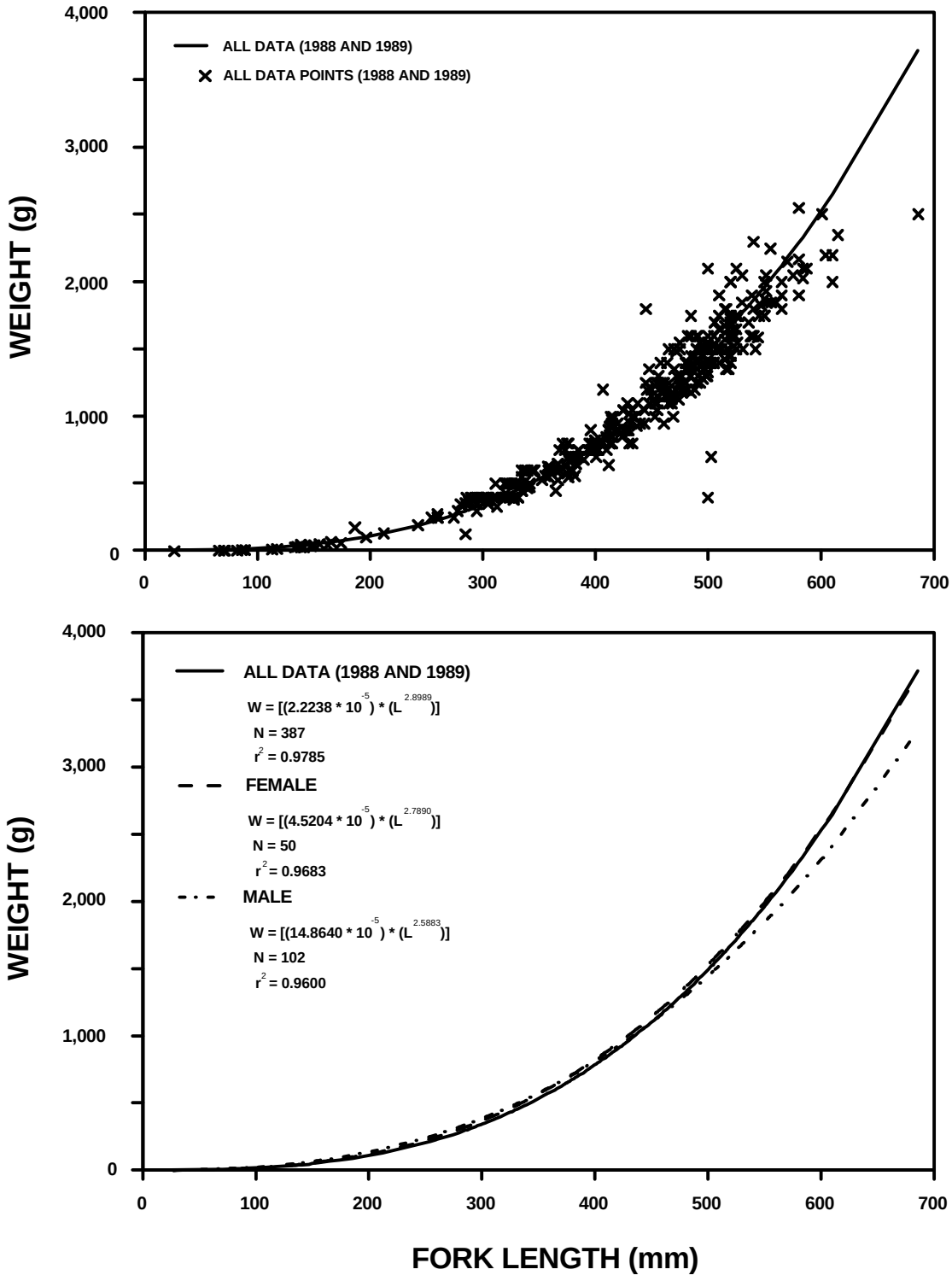

Figure 3.-Length and weight regression model of rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

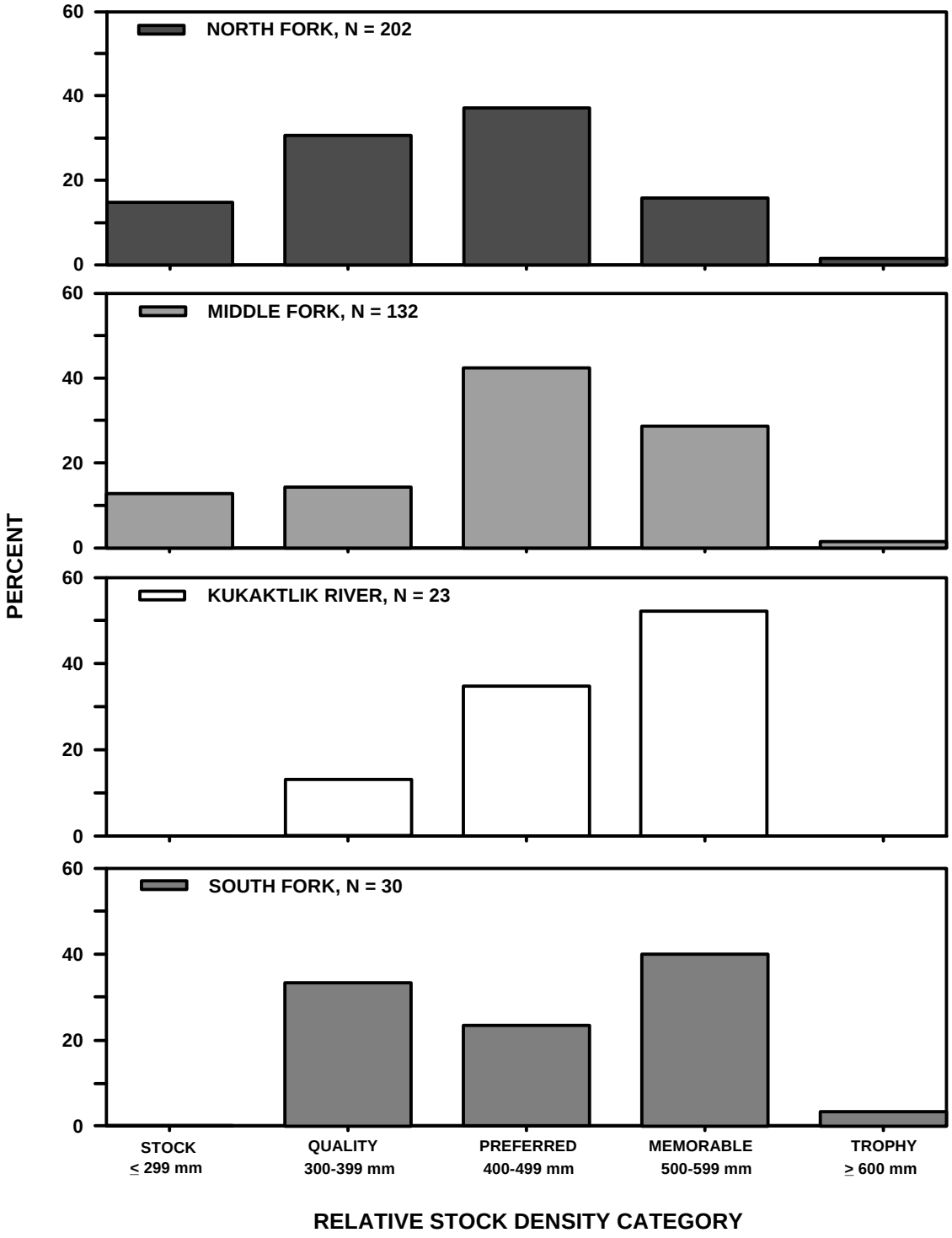

Figure 4.-The relative stock density of rainbow trout from the North Fork, Middle Fork, Kukaktlik River, and South Fork of the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

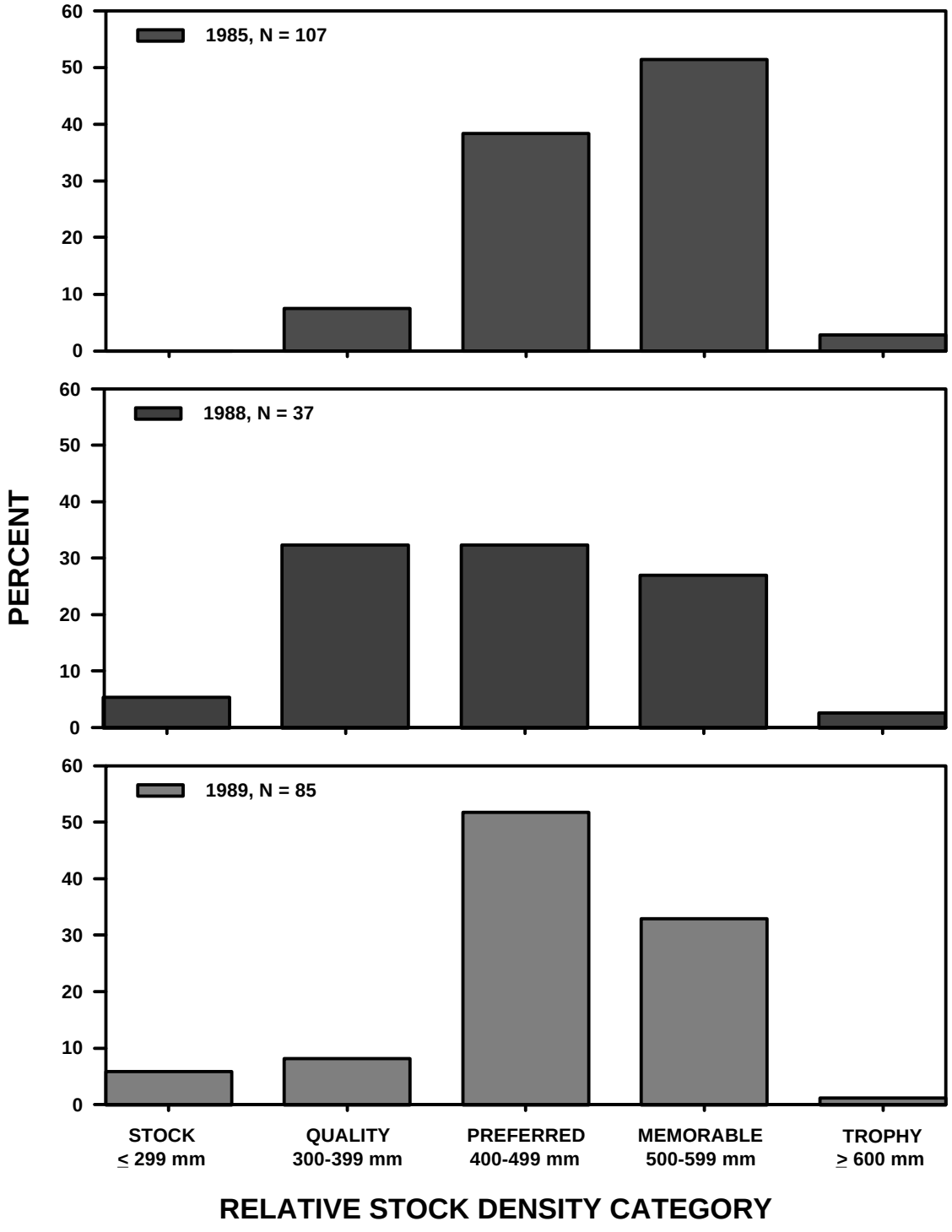

Figure 5.-The relative stock density of rainbow trout from the Middle Fork of the Goodnews River, Togiak National Wildlife Refuge, Alaska, 1985, 1988, and 1989.

Table 2.- Mean length (mm), sample size, and standard deviation of scale aged rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

	Age Class								
Year	0	1	2	3	4	5	6	7	8
1988									
$\bar{X}$	-	-	165.5	322.6	330.5	410.1	471.9	504.1	538.3
N	-	-	2	11	59	38	41	33	8
SD	-	-	31.5	32.3	59.0	44.2	30.1	27.5	45.3
1989									
$\bar{X}$	27.0	78.3	145.1	268.6	380.0	418.1	484.5	498.0	528.5
N	1	6	13	9	2	24	29	12	8
SD	-	8.7	16.9	26.3	3.0	29.2	41.4	34.3	35.2
Combined									
$\bar{X}$	27.0	78.3	147.8	298.3	332.1	413.2	477.1	502.4	533.4
MIN	-	67	114	213	255	326	378	412	471
MAX	-	90	197	382	433	550	555	570	615
N	1	6	15	20	61	62	70	45	16
SD	-	8.7	20.7	40.1	34.6	39.3	35.7	29.6	40.9

Table 3.- Mean length (mm), sample size, and standard deviation of otolith aged rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

	Age Class											
Year	0	1	2	3	4	5	6	7	8	9	10	11
1988												
$\bar{X}$	-	-	160.5	-	316.8	349.1	410.4	490.3	510.6	543.6	546.0	541.8
N	-	-	2	-	31	23	30	14	13	5	4	4
SD	-	-	37.5	-	36.0	42.8	42.1	38.5	38.8	48.1	45.8	52.0
1989												
$\bar{X}$	27.0	78.3	145.1	228.0	377.0	-	-	-	-	-	-	-
N	1	6	13	2	1	-	-	-	-	-	-	-
SD	-	9.5	17.6	21.2	-	-	-	-	-	-	-	-
Combined												
$\bar{X}$	27.0	78.3	147.8	228.0	318.7	349.1	410.4	490.3	510.6	543.6	546.0	541.8
MIN	-	67	114	213	255	288	322	435	413	495	500	500
MAX	-	90	187	243	433	445	469	570	551	604	601	615
N	1	6	15	2	32	23	30	14	13	5	4	4
SD	-	8.7	19.2	15.0	36.4	41.8	41.4	37.1	37.2	43.0	39.6	45.0

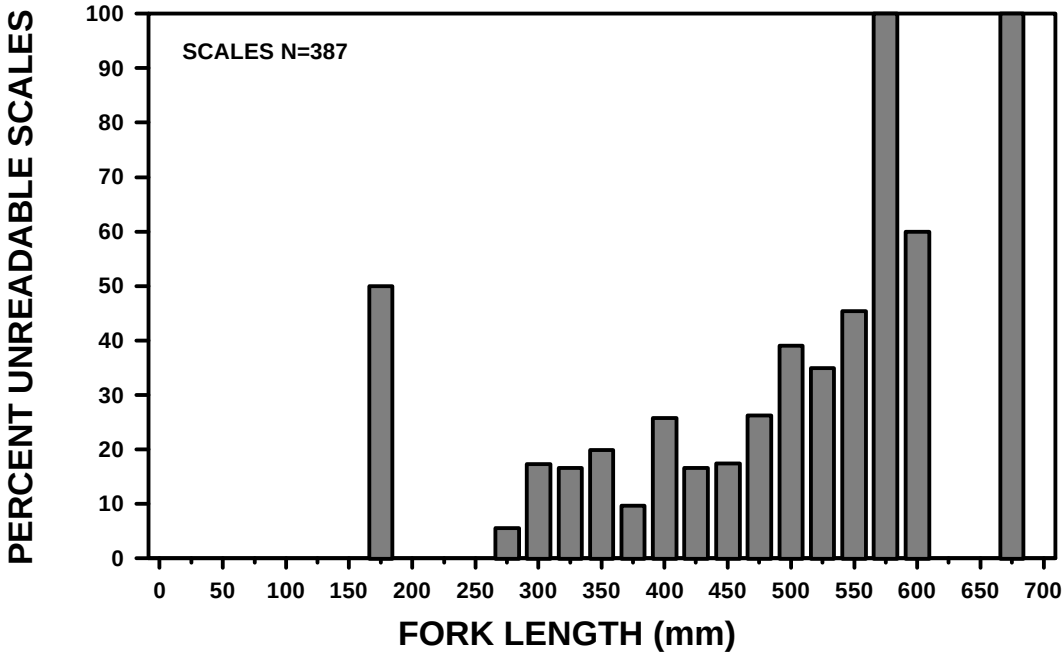

Figure 6.- Percentage of unreadable scales by fork length of rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

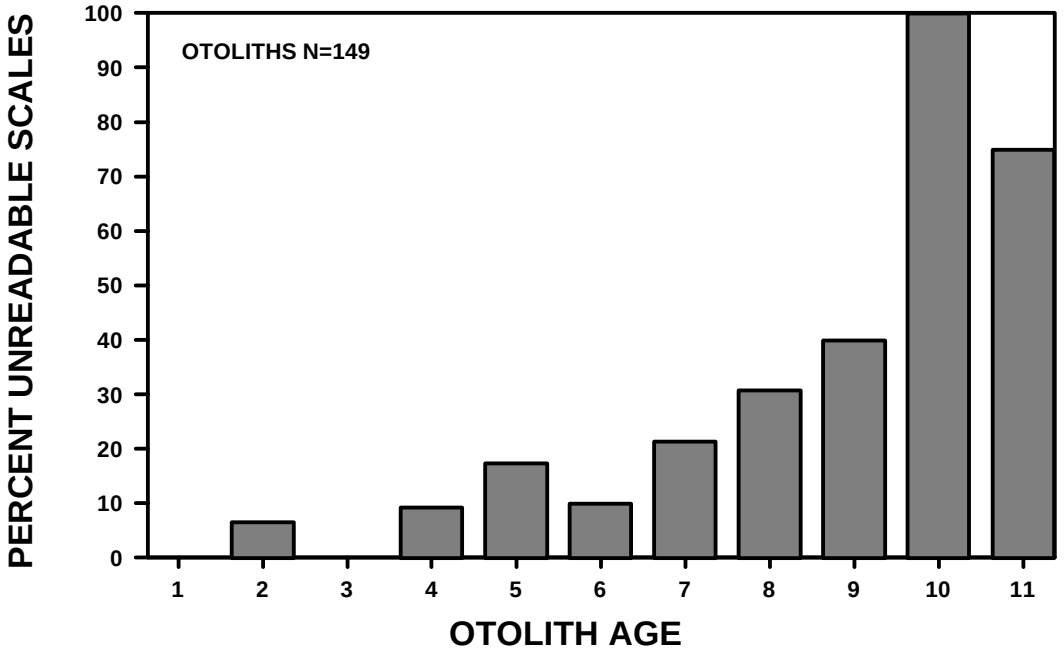

Figure 7.- Percentage of otolith aged rainbow trout where scale ages could not be assigned, Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

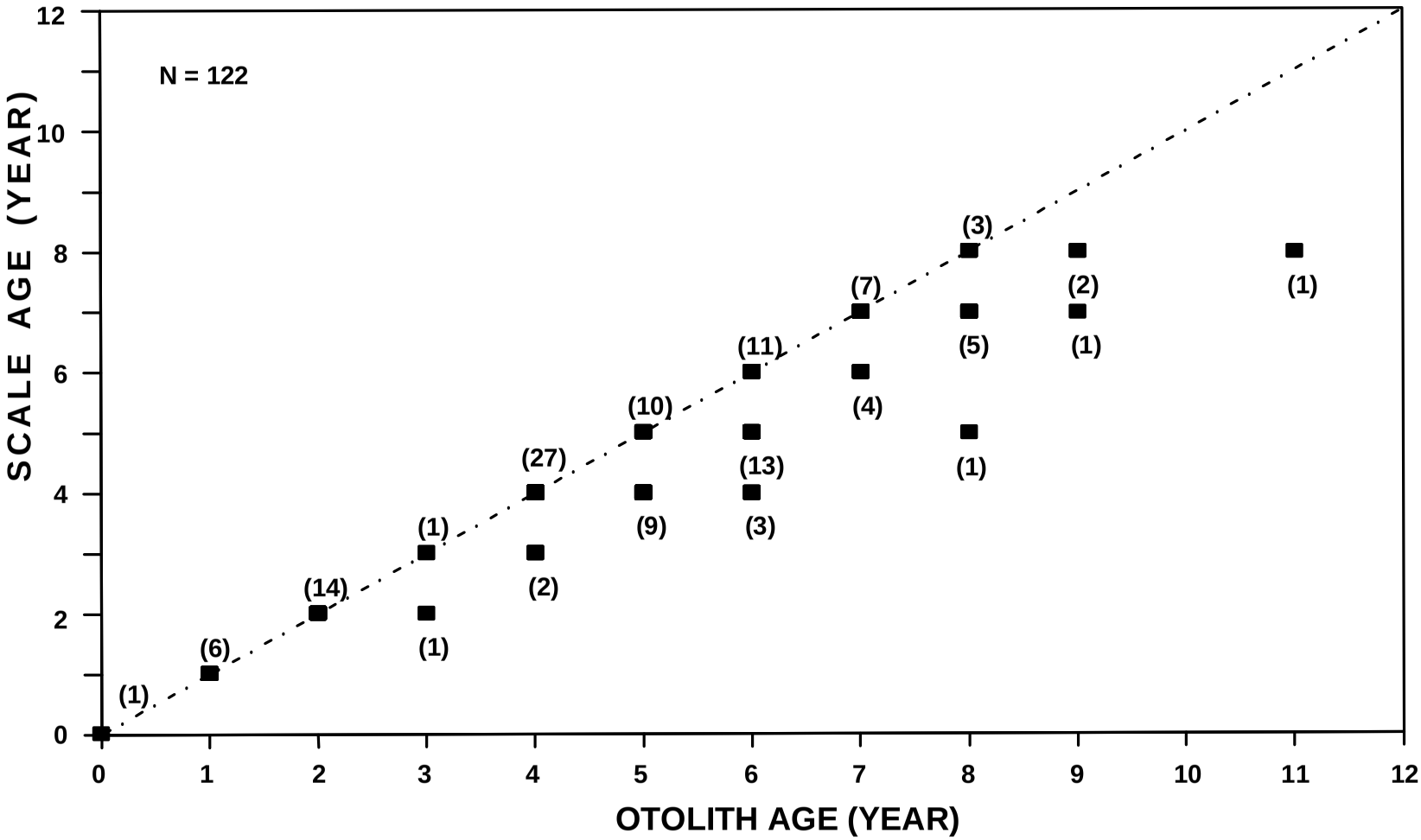

Figure 8.-Relationship between otolith and scale aged rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989. The line represents where scale and otolith ages agree. The number in parenthesis represents sample size.

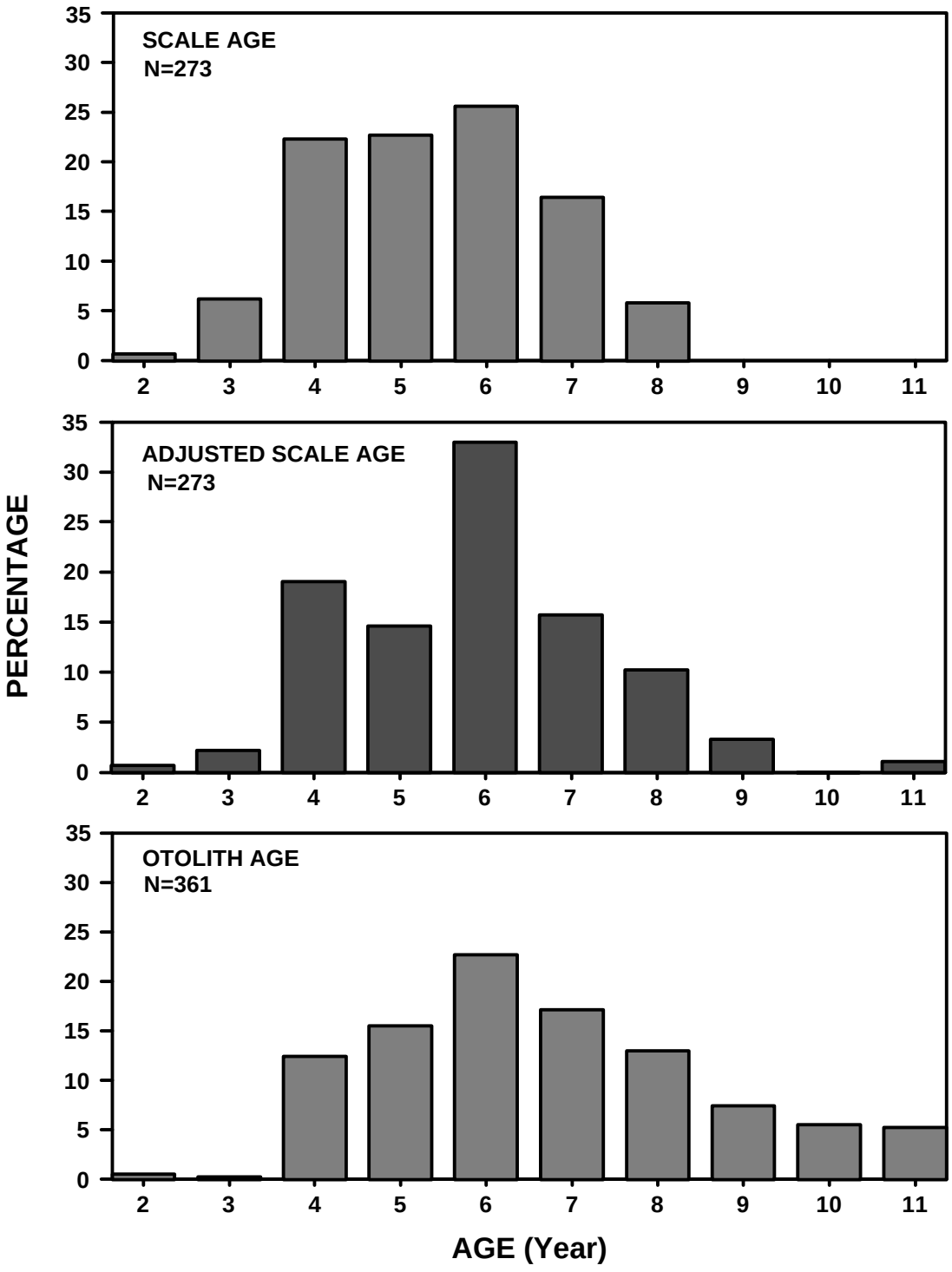

Figure 9.-Age frequencies of scale, adjusted scale, and otolith aged rainbow trout caught with hook and line from the Goodnews River, Togiak National Wildlife Refuge, Alaska, 1988 and 1989.

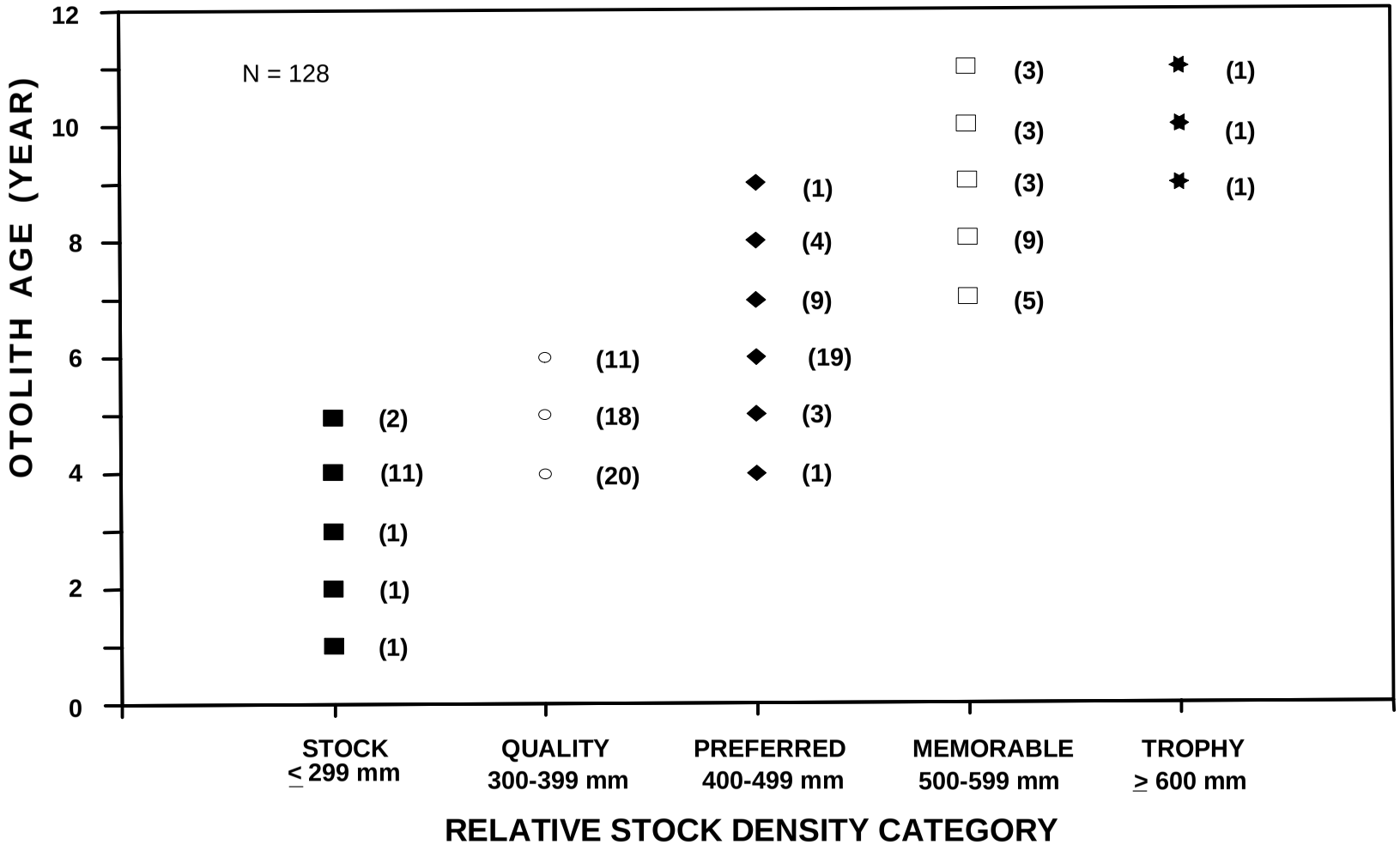

Figure 10.-Relative stock density categories compared to otolith age classes of rainbow trout caught by hook and line from the Goodnews River, Togiak National Wildlife Refuge, Alaska, 1988 and 1989.

(Figure 3). The slopes were compared; females were significantly larger than males ($P<0.025$).

Survival Estimates

The youngest fish caught by hook and line was age 1 and 90 mm FL. Based on the catch curve (Figure 11), rainbow trout became fully recruited into the sport fishery at age 7, although the 4-year-old age class contributes significantly to the sport fishery. Annual survival estimates were relatively constant among years and decreased as ages became older (Table 4). Survival rates based on scale ageing overestimated mortality (Figure 12).

Effort and Catch Estimates

According to the Special Use Permit records, 868 rainbow trout were caught during 949 angler days on the Goodnews River from July through September 1988 (Mark Lisac, U.S. Fish and Wildlife Service, personal communication). Sport catch per unit effort was 0.91 rainbow trout per angler day.

Southwest Alaska Rainbow Trout Stock Comparisons

The mean length of rainbow trout caught by hook and line in the Goodnews River ($\bar{X}$ = 436.7 mm) was significantly greater ($P<0.005$) than that of the Kanektok River ($\bar{X}$ = 422.3 mm). The length frequency distributions (Figure 13) and relative stock density category values (Figure 14) were significantly different for rainbow trout from the Goodnews and Kanektok Rivers ($P<0.005$). There were almost twice as many rainbow trout in the Memorable and Trophy relative stock density categories in the Goodnews River (27%) compared to the Kanektok River (14%) (Figure 14). Slopes of the length-weight regressions (Figure 15) were not significantly different ($P>0.10$).

Rainbow trout scale ages ranged from 0 to 8 years on the Goodnews River, and from 1 to 9 years on the Kanektok River. The modal scale age for both rivers was 6 years (Figure 16). The sex composition of rainbow trout from the Goodnews River was 33% female compared to 54% in the Kanektok River (Wagner 1991). Estimated annual survival rates were similar for each age class (Table 5).

Other Species

Rainbow trout only comprised 3% of all fish captured in 1988 and 1989 (Table 6). Over 11,000 fish of other species were captured, including 4,933 chinook salmon (43%), 2,924 coho salmon (26%), and 1,874 *Salvelinus* sp. (17%). Minnow traps and electrofishing captured 91% of the *Salvelinus* sp. Hook and line sampling yielded 9% of the *Salvelinus* sp. and 100% of the Arctic grayling. Mean lengths and weights ranged from 275-510 mm and 250-1,550 g for Arctic grayling, and from 49-639 mm and 225-2,825 g for *Salvelinus* sp. (Table 7). The length frequency distributions for *Salvelinus* sp. and Arctic grayling were not normally distributed (Figure 17).

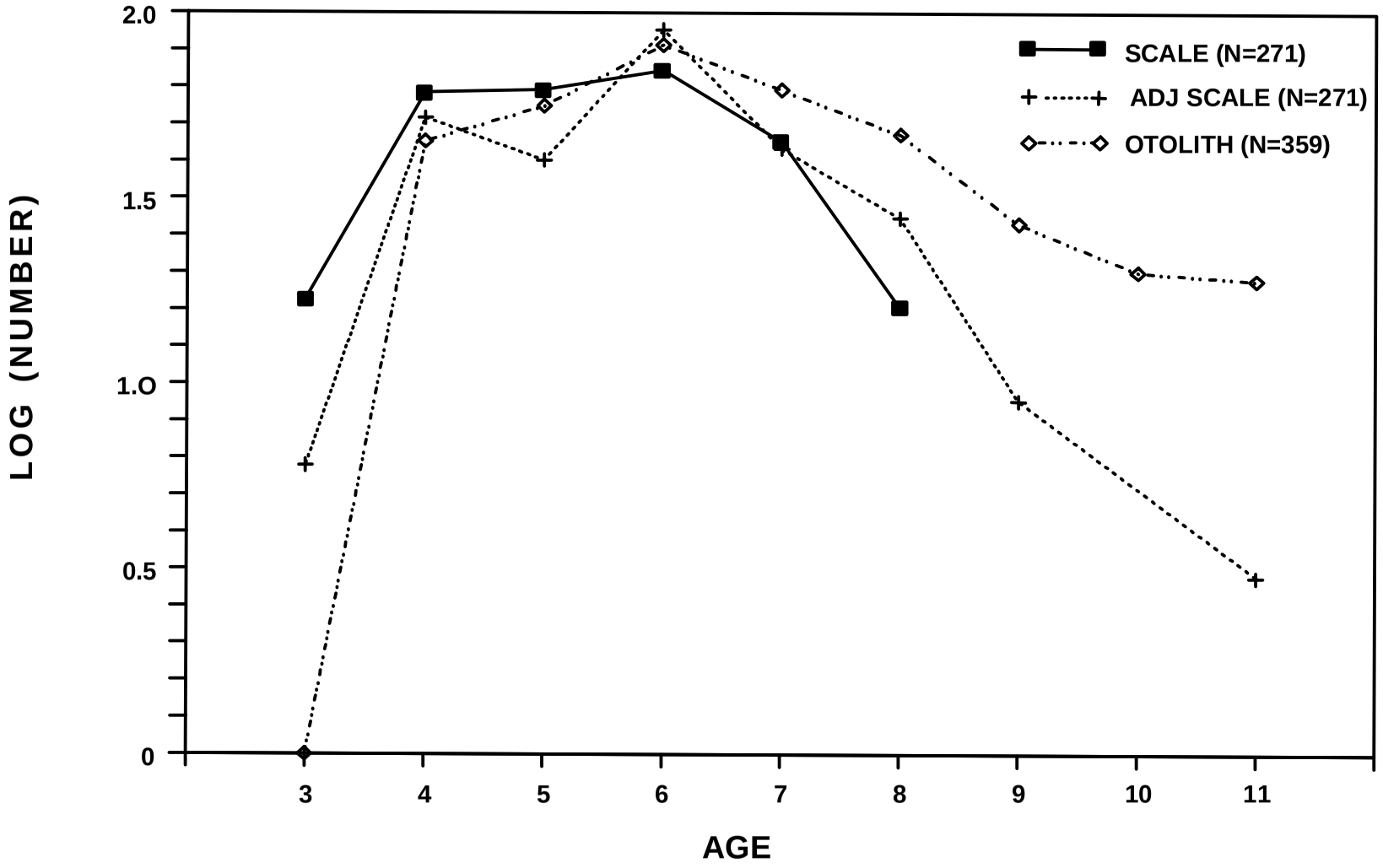

Figure 11.-Catch curve of rainbow trout based on scale ages 3-8, adjusted scale ages 3-11 and otolith ages 3-11, Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

Table 4.-Estimated annual survival rate (s) based on scale ages by year and 95% confidence intervals (CI) for rainbow trout from the Goodnews River, Togiak National Wildlife Refuge 1988 and 1989.

Year	Age	N	s	CI
1988-89	3	20	0.71	0.03
	4	61	0.61	0.04
	5	62	0.52	0.05
	6	70	0.37	0.07
	7	45	0.21	0.09
1988	3	11	0.69	0.04
	4	59	0.59	0.05
	5	38	0.52	0.06
	6	41	0.38	0.08
	7	33	0.17	0.11
1989	3	9	0.73	0.05
	4	2	0.67	0.06
	5	24	0.52	0.08
	6	29	0.37	0.11
	7	12	0.30	0.18

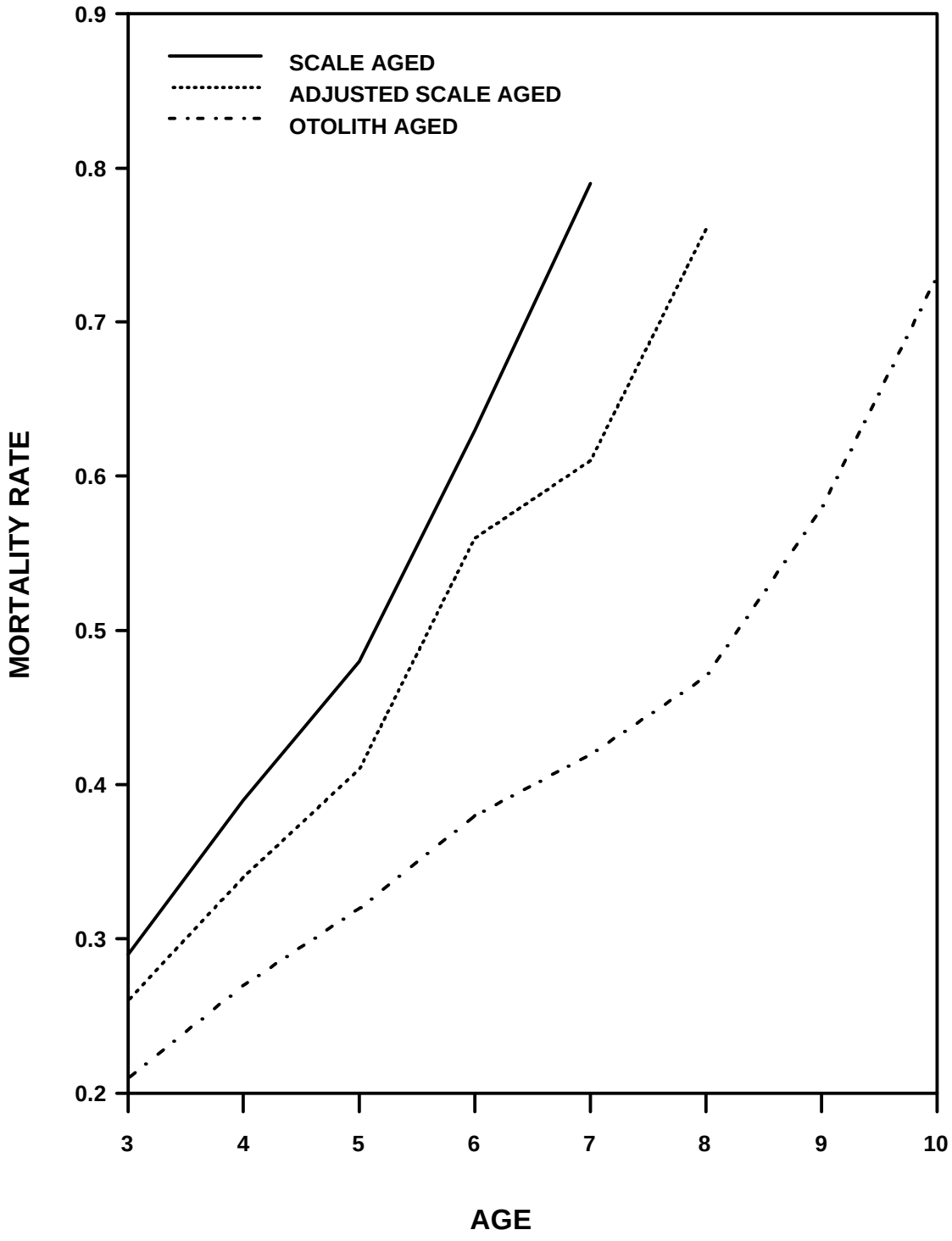

Figure 12.-Mortality rates of scale, adjusted scale and otolith aged rainbow trout from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

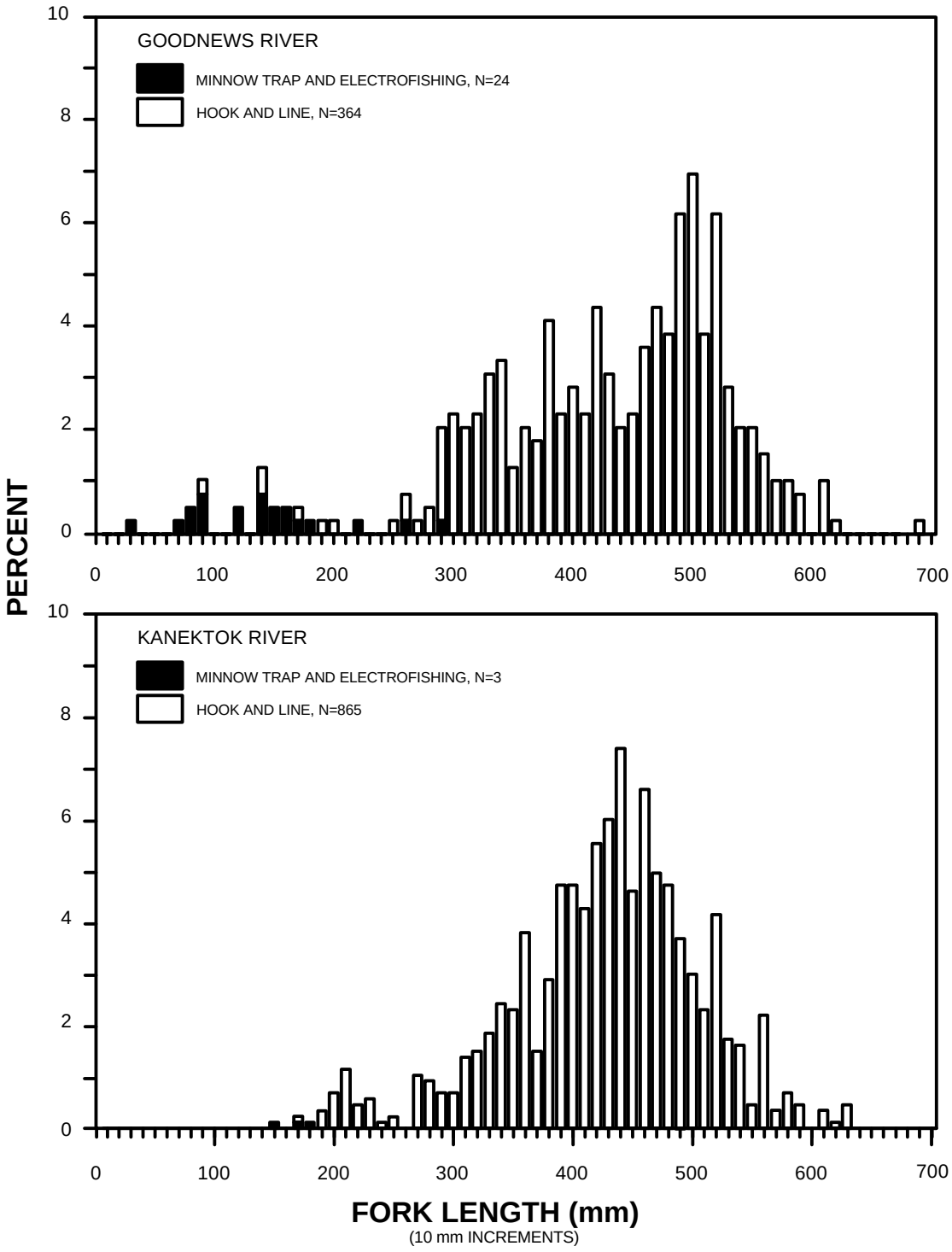

Figure 13.-Length frequency distribution of rainbow trout from the Goodnews River (1988-1989) and the Kanektok River (1985-1987), Togiak National Wildlife Refuge, Alaska.

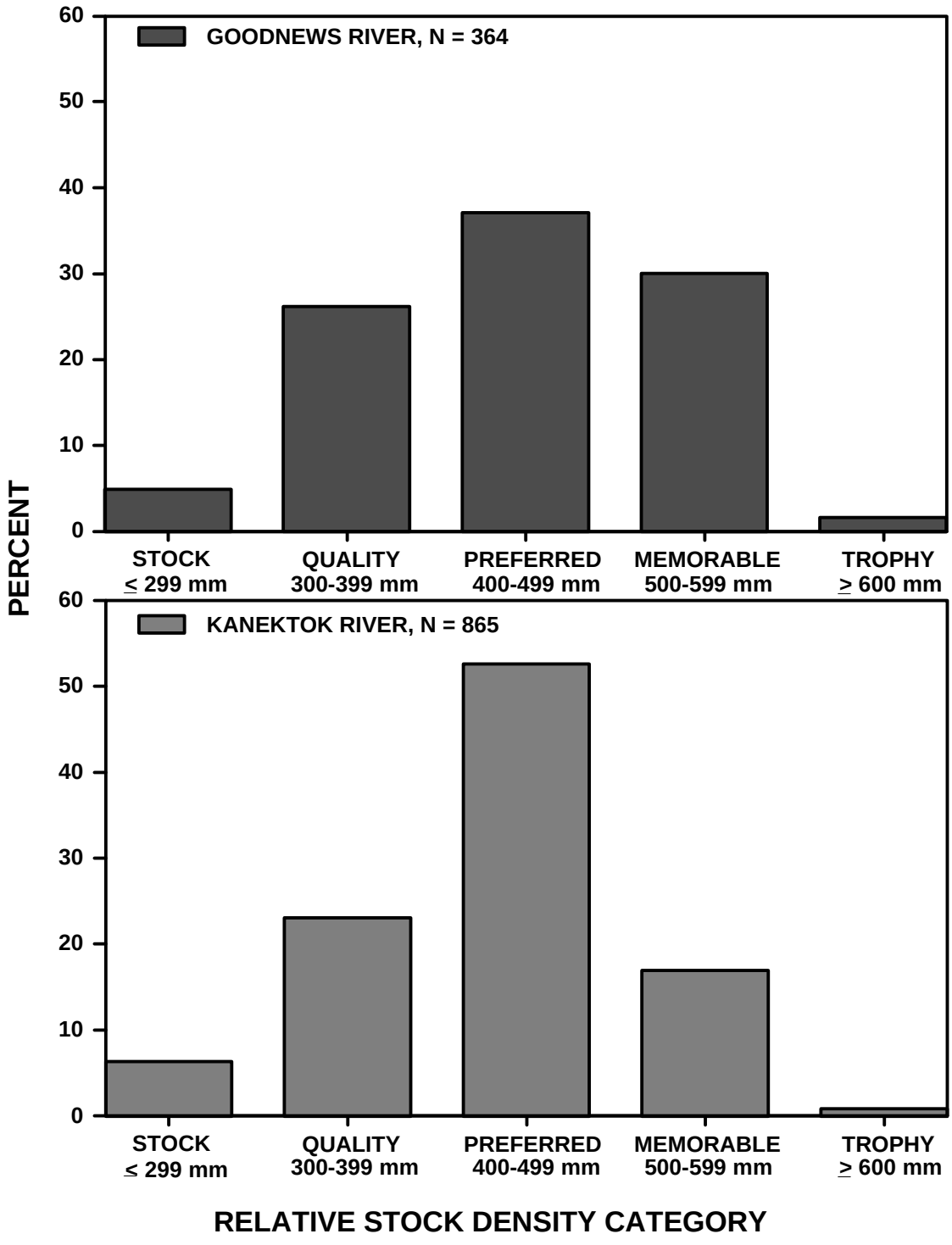

Figure 14.-The relative stock density of rainbow trout caught by hook and line from the Goodnews River (1988-1989) and Kanektok River (1985-1987), Togiak National Wildlife Refuge, Alaska.

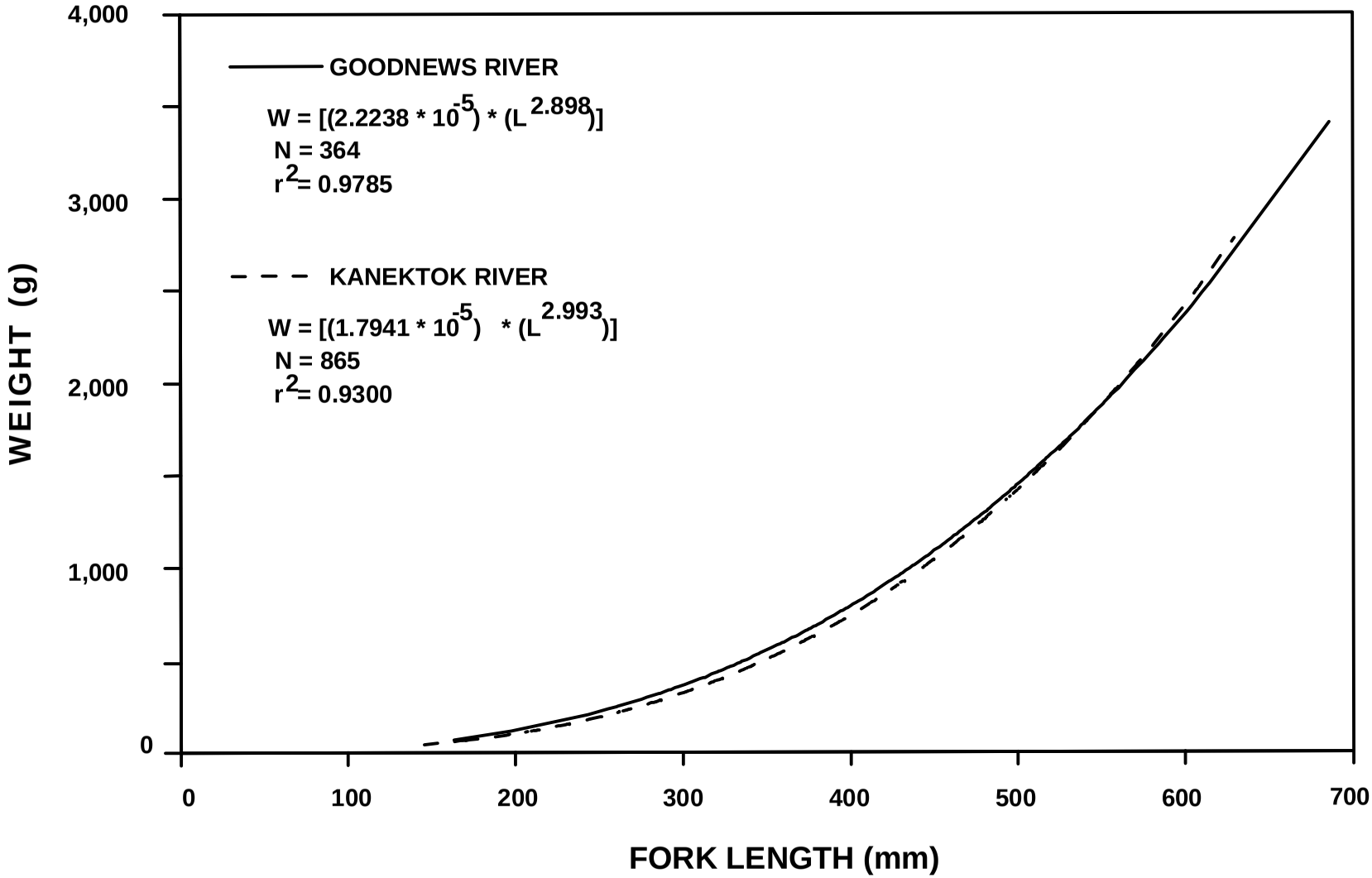

Figure 15.-Length and weight regression models of rainbow trout caught by hook and line from the Goodnews River (1988-1989) and Kanektok River (1985-1987), Togiak National Wildlife Refuge, Alaska.

Table 5.- Comparison of survival estimates of scale aged rainbow trout between the Goodnews and Kanektok Rivers.

Goodnews 1988-1989				Kanektok 1985-1987			
Age	N	s	CI	Age	N	s	CI
3	20	0.71	0.03	3	38	0.73	0.02
4	61	0.61	0.04	4	118	0.65	0.02
5	62	0.52	0.05	5	284	0.53	0.03
6	70	0.37	0.07	6	160	0.35	0.03
7	45	0.21	0.09	7	44	0.22	0.05
8	-	-	-	8	8	0.14	0.09

Table 6.-Species composition and number of fish captured by gear type, Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

	Number Captured				
Species	Minnow Trap	Electro-fishing	Hook and Line	Total	Percent
Alaska blackfish	68	4	0	72	0.6
Arctic grayling	0	0	131	131	1.1
Chinook salmon	3,150	1,783	0	4,933	43.4
Coho salmon	1,601	1,323	0	2,924	25.7
Lamprey sp.	6	7	0	13	0.1
Rainbow trout	7	16	364	387	3.4
Salvelinus sp.	1,120	579	175	1,874	16.5
Slimy sculpin	396	577	0	973	8.6
Sockeye salmon	26	22	0	48	0.4
Threespine stickleback	13	1	0	14	0.1
Total	6,389	4,310	669	11,368	100.0

Table 7.-Length and weight data of Arctic Grayling and *Salvelinus* sp. captured by hook and line, electrofishing, and minnow traps from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

		Length (mm)				Weight (g)			
Species	Drainage	N	$\bar{X}$	SD	Range	N	$\bar{X}$	SD	Range
Arctic Grayling	North Fork	14	417.3	57.3	290-490	14	941.1	337.9	250-1,500
	Middle Fork	71	439.2	39.0	354-497	69	1,062.0	258.6	550-1,500
	Kukaktlik R.	42	433.2	45.9	275-510	41	1,052.4	289.3	500-1,550
	South Fork	4	448.0	25.5	423-470	4	1,015.0	206.8	820-1,300
	Total	131	435.2	43.3	275-510	128	1,044.2	276.1	250-1,550
Salvelinus sp.	North Fork	115	383.3	156.3	49-639	91	1,131.6	432.5	450-2,825
	Middle Fork	167	240.0	191.2	52-636	65	1,245.8	454.2	225-2,600
	Kukaktlik R.	100	164.8	155.2	50-633	18	1,258.3	445.0	700-2,400
	South Fork	-	-	-	-	-	-	-	-
	Total	382	263.5	191.4	49-639	174	1,187.4	443.3	225-2,825

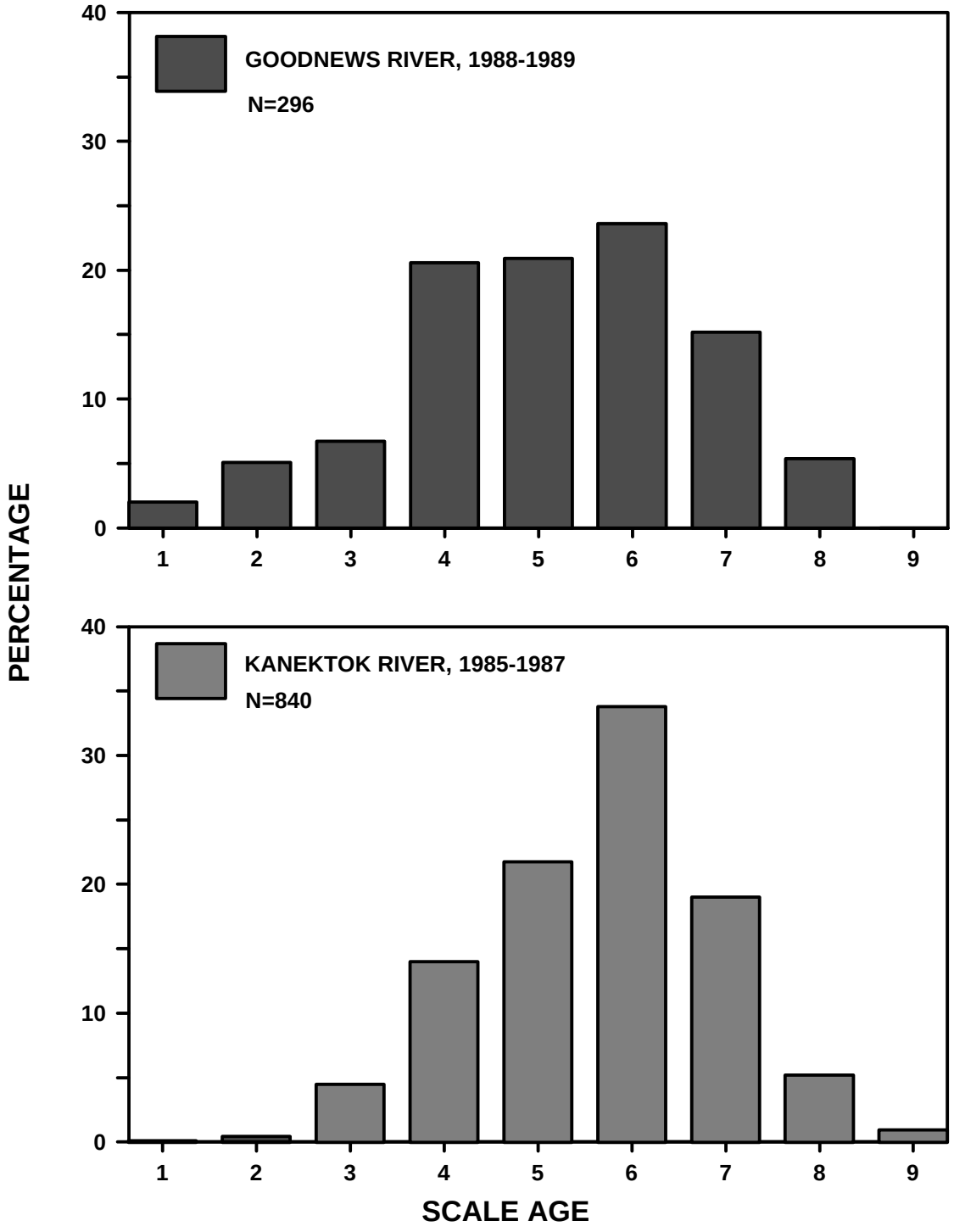

Figure 16.-Scale age distribution of rainbow trout from the Goodnews River and Kanektok River, Togiak National Wildlife Refuge, Alaska.

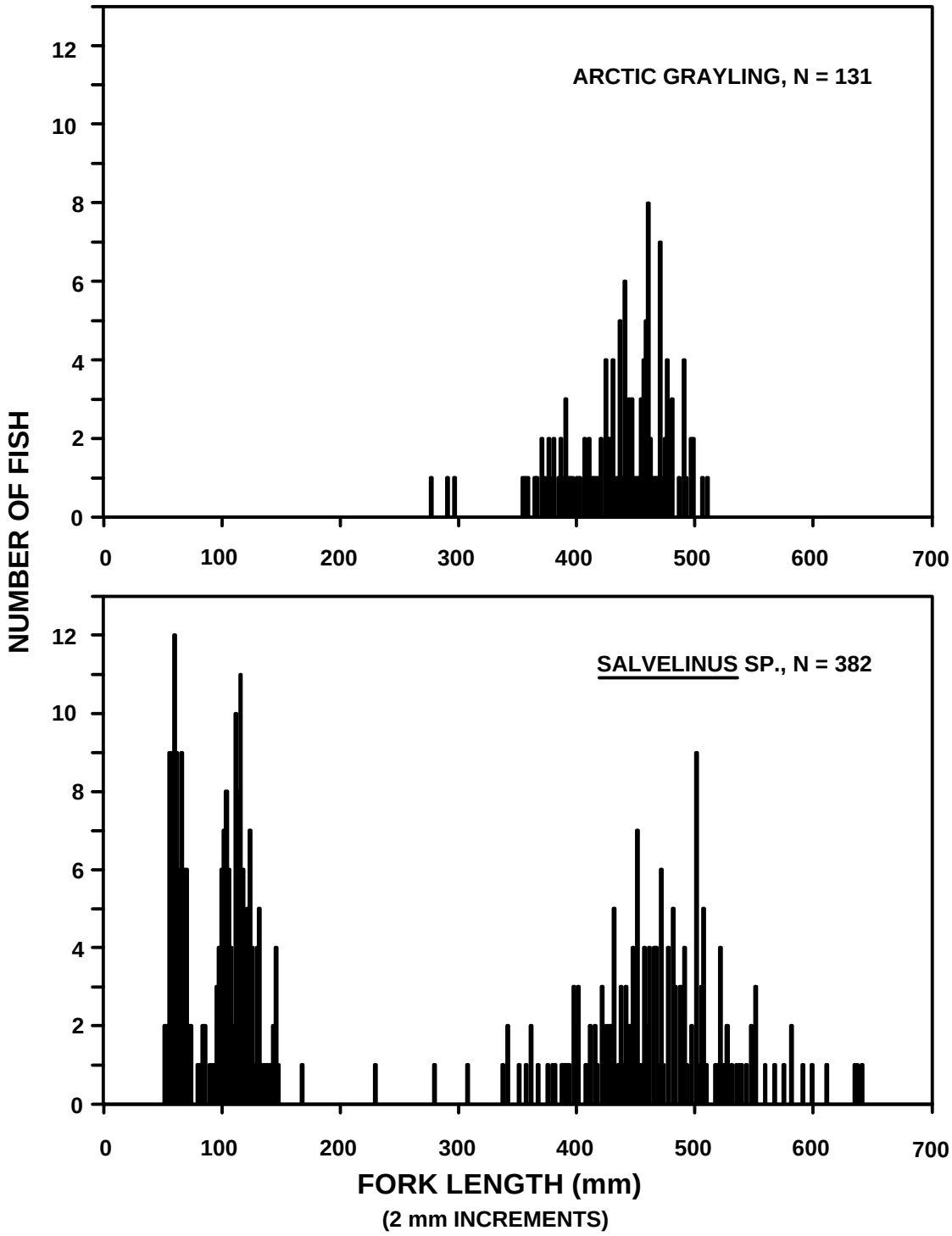

Figure 17.-Length frequency distribution of Arctic grayling and *Salvelinus* sp. from the Goodnews River, Togiak National Wildlife Refuge, Alaska, June-September 1988 and 1989.

DISCUSSION

The otolith sample from Goodnews River indicated a range of age classes and maximum age within the bounds of previous reports. The maximum age for non-anadromous rainbow trout reported by Carlander (1969) was 11 for Eagle Lake, California. Alt (1977) reported a 11 year old rainbow trout from the Goodnews River, and a 10 year old fish from the Kanektok River. Alt's samples were aged by scale analysis. Wagner (1991) reported a 13 year old otolith aged rainbow trout from the Kanektok River.

Scales have been used to age rainbow trout because they are easy to collect, don't significantly harm the fish, and there is a historical database. To validate the scale ages of rainbow trout from the Goodnews River, otoliths were collected from a subsample of all the fish caught. The otoliths showed that many fish were underaged. The underaging became more pronounced in larger fish. The same bias was found for rainbow trout from the Kanektok River. Consistent underaging causes over estimates of growth, recruitment, mortality, and production and could result in management procedures that lead to over exploitation (Beamish and McFarland 1983).

Rainbow trout scales are very difficult to read and are subject to considerable error. The primary sources of error are: (1) slow growth produces tightly spaced circuli with indistinct annuli; (2) scale margin resorption occurs at spawning often making the outer annuli unreadable; and (3) annuli often fail to form during the first winter (Lentsch and Griffith 1987). In addition, our data showed that as length and age increased, the number of regenerated scales increased and the number of fish that the scale reader could assign an age decreased. This inability to assign ages to older fish will bias the results.

Age composition based solely on otoliths from our sample could not be calculated because they were not randomly collected. We feel the sample sizes needed to directly estimate age composition probably would not significantly impact the population if the collection were restricted to reasonable intervals between sampling events. However, the political sensitivity of killing a large number of fish makes this option difficult to implement.

Our option was to collect fewer otoliths and try to estimate age composition using a combination of otoliths and scale age frequency or length frequency. In setting up the project, we hoped we could collect a reference sample of otoliths once and use them to correct scales ages in the future. Using otolith ages to adjust (correct) scale ages did not result in correcting the bias inherent with scales. Older fish were still underrepresented in their true proportion in the population because so few of the older fish had readable scales.

Using a combination of the length frequency distribution and otoliths to estimate the age composition held more promise. This process assumed otolith ages were accurate and that otolith age proportions (by 25 mm groups) reflected the true proportion of ages in that length interval. We felt this method gave the best estimate of age composition but

otolith ages and apportionment based on length frequency still need to be validated.

Management of the Goodnews rainbow trout population is based on maintaining historical age and length composition. Because of the difficulty of accurately aging rainbow trout, this management strategy may not be realistic. An alternative management strategy would be to simply maintain the historical length composition which may automatically maintain the historical age composition. For some populations, length frequency has been used to estimate age composition based on analyzing nodes in the distribution. In slow growing populations, however, length essentially becomes asymptotic and older age classes cannot be reliably separated. Older fish could be lost from the population without noticing a change in the length frequency distribution. Additional data are needed before management based solely on length frequency is adopted.

Within the Goodnews River, variability in mean lengths of rainbow trout between subdrainages was observed. The Kukaktlik River and the South Fork had larger rainbow trout than the Middle Fork, and the Middle Fork had larger fish than the North Fork. The smaller average size in the North and Middle Forks may be due to: (1) greater access and fishing pressure in these areas; (2) naturally occurring fluctuations in fish distributions; and (3) lower fish habitat complexity and cover in the North Fork. These conclusions cannot be confirmed with the available data. Creel survey data for each specific subdrainage would be useful in developing management strategies for the Goodnews River.

Most rainbow trout collected from the Middle Fork in 1985 were in the Memorable category. In contrast, most Middle Fork rainbow trout collected during 1988 and 1989 were in the Quality and Preferred categories. Though these changes may be due to naturally occurring variability of fish populations, harvest or hooking mortality may be impacting larger trout.

A sample of 687 Kanektok River rainbow trout collected from 1985 to 1987 were assigned to relative stock density categories (Wagner 1991). Most of the rainbow trout (caught by hook and line) in the Goodnews and Kanektok Rivers were categorized as Preferred and Memorable. There were more large (>450 mm) rainbow trout represented in the length frequency distribution of the Goodnews River than the Kanektok River. Similar findings were made with an earlier comparison of rainbow trout from the Goodnews and Kanektok Rivers. A sample of 107 Goodnews Rainbow trout collected during 1984 and 1985 were compared to the 1985 to 1987 Kanektok sample (Wagner 1991). These differing proportions may indicate that Goodnews River fish are genetically larger, have a different population structure, or that increased fishing pressure on the Kanektok River may have cropped off the larger rainbow trout.

Length frequency and length categorization systems such as relative stock density can be used to compare rainbow trout populations between years, areas, and management strategies, and to set management objectives for fish stocks. The assignment of minimum lengths for each relative stock density category, and the determination of the number of

categories to be used for Alaskan rainbow trout stocks should reflect varying life strategies of these stocks. Anadromous, lake, and stream resident populations may have very different growth, recruitment and mortality functions, and relative stock density designations should reflect these differences.

Hook and line sampling gave a biased picture of the rainbow trout population length and age composition from the Goodnews River. The length frequency distribution for rainbow trout was not normally distributed, but skewed to the left. This likely resulted from sampling gear selectivity toward larger fish. From catch curve analysis, the slow ascending left limb of the catch curve indicated that age classes 0-5 were not sampled in proportion to their occurrence in the population (Ricker 1975, Everhart and Youngs 1981). The broad flat shape of the catch curve dome indicated that rainbow trout are not fully recruited into the sport fishery until age 7 and older. Four year old rainbow trout comprised the first age class to be strongly recruited into the sport fishery, although the youngest fish was age 1.

Basing all calculations only on hook and line caught samples assumes that all catchable fish are equally vulnerable to the sampling gear. After being caught several times, older fish may become gear shy. The validity of using a single sampling method needs to be assessed.

Increased sampling effort in 1989 to capture young rainbow trout (age 0 - 3) yielded poor results. However, these studies captured large numbers of juvenile *Salvelinus* sp., chinook, and coho salmon. It is likely that sampling was conducted in areas that contained few juvenile rainbow trout. Locating juvenile rainbow trout also proved to be difficult on the Kanektok River (Wagner 1991), and at Gertrude Creek (Jeff Adams, U.S. Fish and Wildlife Service, personal communication).

Due to ageing error associated with scale analysis and the small sample sizes of older fish, survival rates for the oldest age classes in the population are not known. Survival rates for age classes over age 6 or 7 are probably over estimated due to accumulation of erroneously aged older fish. Because catch curve analysis utilizes proportions of the sample in each age category, few older fish in the sample cause the survival rate to be under estimated. Rainbow trout from the Kanektok River (Wagner 1991) and Gertrude Creek (Jeff Adams, U.S. Fish and Wildlife Service, personal communication) exhibited similar survival rates.

Catch per unit effort (CPUE) estimates from sport anglers varied on the Goodnews River. Assuming anglers fished an average of 6 hours per day, the Special Use Permit records from 1988 gave a CPUE of 0.15 rainbow trout per angler hour. A creel survey conducted in 1992 (Mark Lisac, U.S. Fish and Wildlife Service, personal communication) resulted in a CPUE of 0.31 rainbow trout per hour. Differences between the estimates are likely due to the different methods of data collection. Despite these differences, all estimates of CPUE reflect that rainbow trout constitute a small percentage of the total sport catch.

The CPUE on the Goodnews River for rainbow trout was only about one-third that of the Kanektok River. Public use on the Goodnews River was about one-sixth that of the Kanektok River (U.S. Fish and Wildlife Service 1986). Catch data indicated that the density of rainbow trout in the Goodnews River was less than in the Kanektok River.

Few rainbow trout were harvested by the sport fishery because anglers generally practiced catch and release. A creel census conducted on the Goodnews River during 1992 reported that of 371 rainbow trout caught, no trout were harvested (Mark Lisac, U.S. Fish and Wildlife Service, personal communication).

The relatively low fishing pressure and catch and release efforts probably kept fishing mortality levels low on the Goodnews River. Deaths due to delayed hooking and handling stress may be the most significant losses of rainbow trout. A 10% delayed mortality rate was used as a conservative estimate on the Kanektok River (Wagner 1991).

The lack of annual subsistence harvest data of resident fish are of concern. Freshwater fish species including rainbow trout are taken throughout the year (Wolfe et al. 1984), but the magnitude of this harvest is currently unknown.

Little information on acceptable exploitation rates for resident Alaska rainbow trout is available. Lafferty (1989) stated that in the Kenai River, Alaska, a stable population could be maintained with exploitation rates up to 14%. Older age classes of rainbow trout are more vulnerable to overharvest because they can be caught multiple times by sport anglers, which increases the probability of death due to hooking mortality. In addition, large fish are more likely to be retained by sport anglers for mounting as a trophy. The subsistence fishery may harvest a disproportionate number of larger fish because of gear selectivity. Until long term population trends and harvests are evaluated, a cautious approach to management should be followed.

Males outnumbered females 2:1 in the Goodnews River compared to the 1:1 ratio in the Kanektok River. It is unknown why there were twice as many males as females in the Goodnews River sample. The most likely reason is bias due to the timing and/or sampling location, although the differences could be biologically significant.

The fork lengths of *Salvelinus* sp. from Goodnews River were larger than those described for the southern form of anadromous *Salvelinus* sp. from Alaska (Armstrong and Morrow 1980). The fork lengths were within the range of those measured in the Goodnews by Alt (1977). The length frequency distribution was bimodal and was a result of successfully capturing fish using a variety of sample gear. The small fish were caught in minnow traps and by electrofishing while the larger fish were caught using hook and line.

The average fork length of Arctic grayling from the Goodnews was larger than those described in Morrow (1980) and Scott and Crossman (1973). The fork lengths and weights were larger than those of Arctic grayling measured in an earlier Goodnews study, as well as those of the Kanektok

River and Arolic River (Alt 1977). The length frequency distribution for Arctic grayling was skewed. Because Arctic grayling were caught only on hook and line, the gear bias was similar to the bias described for rainbow trout.

Recommendations

Length, weight, and catch per unit effort data indicate that more effort was exerted to catch fewer large rainbow trout on the Goodnews River compared to less effort for more small rainbow trout on the Kanektok River. The greater fishing effort on the Kanektok River may have cropped large rainbow trout from the population. If fishing effort increases on the Goodnews River, rainbow trout in the preferable and trophy relative stock density categories (>500 mm) would likely decrease in numbers.

The Goodnews River was originally selected for study because there was relatively little public use on this system. It was thought that the Goodnews River could be compared with more heavily exploited populations in southwest Alaska to determine the effects of sport fishing effort. It is now apparent that the Goodnews River is receiving enough pressure to cause some impact. Although it still receives relatively light fishing pressure, it is evident that the Goodnews River supports a smaller population of rainbow trout which may be vulnerable to increases in fishing pressure. We cannot conclude if there are significant impacts to this rainbow trout population, but use of this system as a control would be inappropriate.

We recommend that the Refuge should require more complete reporting by Special Use Permittees and that public use surveys be increased. The Special Use Permit reporting should be revised to include effort, catch, and harvest by species and drainage. More complete data could be recorded in pre-printed daily log books provided to each permittee, with instructions and request for specific data. In addition, the rainbow trout population should be sampled every five years. Comparisons should be made with updated and baseline data to note any trends in population structure. Finally, we believe that a conservative approach should be practiced in management of this resource, thereby maintaining the existing Goodnews River rainbow trout population.

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REFERENCES

Alt, K.T. 1977. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Federal aid in fish restoration. Alaska Department of Fish and Game, Division of Sport Fish, Volume 18, Juneau, Alaska.

Alt, K.T. 1986. Western Alaska rainbow trout studies. Federal aid in fish restoration, F-10-1. Alaska Department of Fish and Game, Division of Sport Fish, Volume 27, T-6-1, Juneau, Alaska.

Armstrong,R.H. and J.E. Morrow. 1980. The Dolly Varden. Pages 99-140 in E.K. Balon, editor. Charrs: salmonid fishes of the genus *Salvelinus*. Dr. W. Junk bv publishers, The Hague, The Netherlands.

Barber, W.E. and G.A. McFarlane. 1987. Evaluation of three techniques to age Arctic char from Alaskan and Canadian waters. Transactions of the American Fisheries Society 116:874-881.

Beamish, R.J. and G.A. McFarlane. 1983. Validation of age determination estimates: the forgotten requirement. Transactions of the American Fisheries Society 112:735-743.

Brothers, E.B. 1987. Methodological approaches to the examination of otoliths in ageing studies. Pages 319-330 in R.C. Summerfelt and G.E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames, IA.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames, IA.

Chapman, D.G. and D.S. Robson. 1961. The analysis of a catch curve. Biometrics 16(3):354-368.

Draper, N.R. and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, Inc., New York, NY.

Everhart, W.H. and W.D. Youngs. 1981. Principles of fishery science. Cornell University Press, Ithaca, NY.

Gabelhouse, D.W. 1984. A length categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Jearld, A. 1983. Age determination. Pages 301-324 in L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, MD.

Koo, T.S.Y. 1962. Age designation in salmon. Pages 37-48 in T.S.Y. Koo, editor. Studies of Alaska red salmon. University of Washington Press, Seattle, WA.

Lafferty, R. 1989. Population dynamics and exploitation of rainbow trout, Kenai River, Alaska. Masters Thesis. University of Alaska, Fairbanks, Alaska.

Lentsch, L.D. and J.S. Griffith. 1987. Lack of first year annuli on scales: frequency of occurrence and predictability on trout of the western United States. Pages 177-188 in R.C. Summerfelt and G.E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames, IA.

Lisac, M.J. 1989. Estimated public use within Togiak National Wildlife Refuge 1984 - 1988. U.S. Fish & Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK.

MacDonald, R. 1993. Estimated public use within Togiak National Wildlife Refuge 1989 - 1992. U.S. Fish and Wildlife Service, Admin. Rep., Dillingham, AK. (unpublished).

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, Alaska.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry, The principles of statistics in biological research. Second Edition. W.H. Freeman and Company, New York, NY.

U.S. Fish and Wildlife Service. 1986. Togiak National Wildlife Refuge final comprehensive conservation plan, wilderness review and environmental impact statement. U.S. Fish and Wildlife Service, Anchorage, Alaska.

U.S. Fish and Wildlife Service. 1990. Fishery management plan, Togiak National Wildlife Refuge. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Wagner, T.A. 1991. Southwestern Alaska rainbow trout investigations, Kanektok River, Togiak National Wildlife Refuge, Alaska. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 10, King Salmon, Alaska.

Wege, G.J. and R.O. Anderson. 1978. Relative weight (Wr): a new index of condition for large-mouth bass. Pages 79-91 in G.D. Novinger and J.G. Dillard, editors. New approaches to the management of small impoundments. Special Publication 5, North Central Division, American Fisheries Society, Bethesda, MD.

Wolfe, R.J., J.J. Gross, S.J. Langdon, J.M. Wright, G.K. Sherrod, L.J. Ellanna, V. Sumida, and P.J. Usher. 1984. Subsistence-based economies in coastal communities of Southwest Alaska. Alaska Department of Fish and Game, Division of Subsistence, Technical paper No. 89, Juneau, Alaska.